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	Page
Essential Plant Food Elements — OSWALD SCHREINER	307
Fertilizers Increase the Total Yield and Percentage of Large Sized Potatoes — A. W. BLAIR	321
Crop and Market News	324
Notes	328
Review of Recent Literature	333

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Essential Plant Food Elements*

By OSWALD SCHREINER, Soil Fertility Investigations,
Bureau of Chemistry and Soils, United States Department of Agriculture

We have considered for more than half a century that only the ten elements, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, carbon, hydrogen, oxygen, and iron, were necessary for growth and maturation of our agricultural crops. In fertilizer practice, to increase crop growth, we have contented ourselves chiefly with the application of nitrogen, phosphorus, and potassium to our soils, with lime to correct soil acidity and not as plant food, on the assumption that soils, fertilizers, and manures supply sufficient of the other mineral elements for profitable crop production. Modern researches

*Address delivered at the meeting of the Del-Mar-Va Peninsula Fertilizer Association, Ocean City, Md., June 28, 1930.

NOTE—Important changes have taken place in fertilizer usage in recent years making it essential that potato growers keep themselves informed concerning developing trends. Dr. Schreiner discusses some of the new factors in fertilizer practice relating to the influence of the lesser known elements on plant growth and production and also touches upon the use of concentrated fertilizers.

He and some of his associates are very much interested in soil fertility and fertilizer problems affecting potato growers and are conducting cooperative work on prominent soil types with a number of Agricultural Experiment Stations along such lines. The potato in common with other crops, has shown a marked response to some of the so-called rare elements under certain soil conditions to which Dr. Schreiner refers. The term "rare" is used largely in the sense of "uncommon" with respect to fertilizer usage. These minor elements, however, as Dr. Schreiner points out, may easily become of major significance once a shortage develops.

It is felt that what Dr. Schreiner has to say will be of considerable interest to growers and others who may be interested in potato production.—(Editor).

have shown us strikingly that magnesium, iron, sulphur and manganese deficiencies can exist in comparatively large soil areas. Similarly, we have been able to show a marked phosphorus deficiency in some middle western soil regions of the United States devoted to sugar beet culture, so that the application of even small amounts of this element produces large increases in sugar beet production, and in sugar content of the beets.

Agricultural chemists and plant and animal physiologists quite naturally have given first attention to those elements present in plants and animals in largest amount. With the development of research in analytical chemistry and in biochemistry, and with more delicate and refined methods and apparatus, it is to be expected that the less common elements considered previously as non-essential, will be found to be most important factors in plant and animal nutrition, metabolism, and health. I am referring especially to the functions which elements like manganese, copper, boron, iodine, zinc, arsenic, barium, strontium, caesium, titanium, chromium, vanadium, aluminum, and silicon play in the newer research in plant and in animal physiology.

The nutrition studies of Reed and Haas in southern California on citrus trees grown in water cultures illustrate the absolute necessity of the presence of some of these rarer elements, although they did not determine which of them were specific in remedying the observed physiological disturbances. With all usual plant foods present in complete culture solutions they observed normal growth at first, but sooner or later serious symptoms of malnutrition developed. The orange leaves recurved or rolled strongly, and the midribs thickened and frequently split open. The leaves showed yellowish spots whose centers often had resinous exudations, and the shoots frequently showed the formation of multiple buds, symptoms which are usually associated with the disease known as dieback in citrus orchards. All these physiological disturbances disappeared on treatment with a mixture of the salts of the less common elements, aluminum, iodine, titanium, bromine, strontium, lithium, manganese and boron.

The excellent work of McHargue in Kentucky with manganese in controlled solution cultures shows conclusively that it must be considered one of the elements essential to plant growth. He also reaches the conclusion that not only manganese, but other elements which he has shown to be present in the germs and pericarps of seeds, in the leaves of plants and in Kentucky bluegrass especially, such as copper, zinc, nickel and cobalt, play a part in the vitamin cycle in nature, and that they aid plants in synthesizing organic combinations

which function as catalysts, enzymes and vitamins and in turn, upon entering the animal system as food, are resynthesized into hormones, oxidizing and catalyzing enzymes, the animal vitamins so essential to proper growth and function.

The use of manganese in agriculture has been increased in the last few years as the result of some practical demonstrations with tomatoes and other truck crops in southern Florida. These demonstrations were based on research work by scientists of the Department of Agriculture which have been conducted over a period of years and tended to show that manganese was essential to plant growth for without it plants showed abnormal symptoms, analogous to disease conditions.

As manganese is widely distributed throughout the United States, most soils contain sufficient for profitable crop production, but in certain sections where manganese is rare in rocks and soils, or where conditions are such that the manganese is unavailable to plants, serious difficulties are experienced.

South of Miami, Florida, there are large areas that have been in the past, and are yet, periodically covered with water each year. This soil, composed almost entirely of calcium carbonate deposited from the sea water, contains also from 5 to 10 per cent organic matter, small amounts of the usual plant foods, a little silica, traces of iron and a few other minerals with manganese barely discernible by delicate tests. These areas, known as Glades, are being used largely for the production of tomatoes. The manner of growing tomatoes is as follows: As soon as these level fields permit cultivation after the water has receded in the late fall, the growers mark off rows and drop tomato plants a certain distance apart and throw on a handful of manure. This has been the only method that has proved successful. When the manure application is large and continuous year in and year out, tomatoes can be grown successfully. If, on the other hand, no manure is used or the soil is stirred up, as is ordinarily done in other regions by plowing or cultivating, the tomatoes will not grow well and no amount of fertilizer helps the situation.

Analysis of the soil disclosed the fact that the difficulty was a lack or a deficiency of manganese. The manure comes from the Mississippi River Valley and other points in the United States and carries the manganese which the forage plants have absorbed by growing on soils in regions where this element is common.

A chlorotic condition of the foliage of the tomato plants grown on this manganese deficient soil manifested itself in white spots and areas between the veins. This could not be remedied with liberal applications of ordinary fertilizer salts,

but the addition of minute quantities of manganese—50 pounds of manganese sulphate per acre, with an acre foot of soil weighing about four million pounds—produced strong, vigorous plants, deep green in color, luxuriant blossoming, and greatly increased fruit production. In fact, without manganese there is no fruit production, and the plants soon fade and die.

It is especially interesting to note that tomato plants set without manure, compost or peat, lived, thrived and produced a good crop, when manganese sulphate was added to the soil. When set without compost and without maganese sulphate many plants died and those that survived produced but little. It was demonstrated that tomatoes can be grown in the Glade soils with manganese salts and fertilizers alone, without having manure present, or peat can be substituted for manure, by treating the peat with manganese sulphate.

Some of the results obtained were as follows: With commercial fertilizers and peat, without manganese, there was a production of 76 crates per acre and where manganese was mixed with peat, 237 crates. On a second field and a much more productive soil, there was a yield of 270 crates with fertilizers and peat, as compost, and 496 crates when manganese was mixed with peat. On a third field fertilizers and peat as compost gave a yield of only 80 crates and where manganese was mixed with the peat 260 crates per acre.

When manganese sulphate was used with commercial fertilizer but without compost of any kind some of the results were as follows: With manganese sulphate used at the rate of 50 pounds per acre and applied at the time plants were set, a yield of 456 crates per acre was obtained. Where the manganese was omitted, the crop was a total failure and produced no tomatoes. On another field, there was a yield of 12 crates, without manganese, while with 50 pounds of manganese sulphate, there was a yield of 177 crates per acre. On a third field there was a yield of 94 crates where no manganese was used and 234 with manganese. In all of these tests the commercial fertilizers were used at the rate of two tons per acre on all the plots. Whether manganese was used or not, they used, nevertheless, two tons of fertilizer per acre, and yet the tomatoes would not grow and flourish unless the manganese were present.

A number of large-scale experiments were made with growers, using one-acre plots, to determine the effect of manganese sulphate. In these tests the cooperating farmer used and applied the material, some mixed it in with the commercial fertilizers, others applied it as a separate application. Some

used stable manure, while others relied entirely on the manganese sulphate. Eighteen of these large-scale experiments were made and each showed a substantial increase resulting from using manganese sulphate. A successful crop was produced by those who had used the manganese sulphate, even without stable manure.

Tomato growers of southern Florida have begun to use manganese sulphate on a large scale within the last two years, and this has replaced stable manure to a large extent. Formerly, train loads of compost were carried to the field where today a few carloads of manganese sulphate are giving the same results. Growers who till these calcareous glade soils haul out a few bags of manganese sulphate instead of truck loads of manure.

Manganese sulphate is now also used generally in the area south of Miami in the growing of beets, carrots, lettuce, cabbages, corn, potatoes, beans, ornamentals and forage crops, whereas formerly these crops were considered failures on this land. This has given us an opportunity to make a thorough study of the effect of the manganese on these various crops. With each of these crops commercial fertilizers were used in abundance, but manganese was omitted on a section of the field. All the crops grown without manganese were chlorotic and mottled, made a poor growth and produced little or no marketable vegetables. The growth was very good where manganese was used and only 50 pounds were required to produce this remarkable difference in yield, the difference between success and failure in economic crop production.

Some of the results obtained were as follows: Without manganese, snap beans yielded 230 pounds per acre against 6,720 pounds with manganese added. Similarly, cabbages gave without manganese a yield of 16,236 pounds per acre as against 42,107 pounds with manganese. Potatoes without manganese gave only 65 bushels per acre and with manganese, 180 bushels. Carrots and beets grew to three and four times the size with manganese as without manganese and cauliflower heads were nearly double the weight where manganese was used with similar results on the other vegetables.

Another interesting case of manganese deficiency has occurred in the section on the east coast, north of Fort Lauderdale in Broward County. This section produces beans and peppers. The soil is sandy in nature and the surface is slightly acid. At intervals in the section, small areas occur which contain shell deposits. These shell areas appear as pockets and lie slightly lower and are alkaline. Both beans and peppers were found to fail in the pocket areas. The plants became

yellow, were very chlorotic, dwarfed, and failed to grow and produced no vegetables. A small amount of manganese overcame the trouble, and when used, the crops grew normally and produced as much as the surrounding section which showed no chlorosis.

Similar cases have been observed elsewhere. Throughout eastern North Carolina, there occur in fields unproductive spots on which corn and especially soybeans show symptoms of chlorosis resembling manganese deficiency. These soil spots are approximately neutral or alkaline while adjacent soils in the same fields, bearing normal crops, are acid. These spots often result from local over-liming, due to lime piles, when spreading lime on the fields, or to the burning of brush heaps in clearing. Willis has been studying such spots and finds that the chlorotic poor growth of the soybeans can be completely obviated by the application of manganese sulphate.

These experiments demonstrate beyond doubt that, whatever the fundamental function of manganese may be, the element is indispensable to the normal growth of plants. Although these soils are of a unique type, owing to their exceedingly high calcium carbonate content, and are exceptional in possessing a negligible manganese content as compared with the general run of American soils, they, nevertheless, furnish a striking illustration of the kind of problem that may arise more frequently in the future.

An interesting comment on the action of manganese has recently been made by Samuel and Piper of the University of Adelaide in Australia in their excellent demonstration of the essential character of this element. Excluding manganese completely from their water cultures, they found that the plants might grow with the amount of manganese stored in the seed, in certain cases for weeks and then the manganese deficiency symptoms developed with disease-like suddenness. They obtained astonishing differences in growth as a result of the complete absence of manganese on the one hand, and the presence of mere traces on the other, amounting to from 300 to 5,000 per cent. Different plants require different amounts of manganese to enable them to complete their development. Therefore, certain types of soil, which do not possess sufficient available manganese for the growth of cereals, may support an apparently normal growth of pasture plants and weeds, but nevertheless contain less manganese than the same plants grown on normal soil, which fact, according to Samuel and Piper, may be found to have some connection with certain animal diseases which occur on these manganese deficient soils in South Australia.

I should here add a word of caution against too promiscuous

a use of manganese, for not only is this uneconomic, but a too liberal supply of manganese will cause harmful results. I may recall to you in this connection the fact that on certain soils in the Hawaiian Islands difficulty was experienced in the growing of pineapples and that this was shown to be due to the presence of an excessive amount of manganese in the soils, up to 8 and 10 per cent. Similar harmful effects have been obtained by investigators in greenhouse experiments with many plants where too large an amount has been used.

Another point should be here emphasized and that is that we have obtained thus far results only with soluble manganese salts and the sulphate is the one best suited for the purpose. Manganese occurs in nature well distributed and most soils contain some of it. Manganese occurs in quite a number of localities of the United States where it can be mined and where sufficiently pure it is manufactured into the various manganese preparations used in the arts and industries. Manganese sulphate, pure or containing such impurities as iron and some other metals, is frequently obtained as a by-product, and this can be used in fertilizers for supplying water soluble available manganese to such soils as may be shown to be deficient. It is, on the other hand, not possible to utilize directly many of the impure manganese ores, manganese bearing slags, and other insoluble manganese compounds without previous treatment with sulphuric acid to convert the insoluble manganese into soluble manganese and hence available manganese. None of the natural occurring manganese materials which we have so far tested has given us any appreciable response in combating the symptoms of manganese deficiency in plants.

With the utilization of modern pure fertilizer materials of chemical manufacture, especially in the leachy sandier soils the problem may be extended to include not only manganese, but also such elements as zinc, copper, nickel, boron, and so forth, the relation of which to plant growth is not yet so fully understood.

There are many troublesome and little understood plant diseases which may be directly traced in the future as being due to manganese deficiency or to a deficiency of some other little understood essential element, the frenching of citrus and dieback as already mentioned, possibly pecan rosette, which like manganese deficiency in the tomato, has been alleviated by manure and mulching with organic matter and various other so-called physiological diseases which have baffled the pathologists. Samuel and Piper have shown that the disease of oats, occurring in South Australia on certain soil types and also on alkaline soils in Germany and Sweden, is a manganese deficiency disease due to a lack of available manganese in the

soil. Although manganese occurs in this Australian soil, it is not soluble and available in sufficient quantity to supply the needs of the plants and this same condition, no doubt, occurs on many of our own soils and as Willis and Mann have pointed out, this may occur under unfavorable climatic conditions, such as excessive rains, almost anywhere. A small amount of soluble manganese may therefore become desirable in fertilizers as a kind of insurance against unfavorable climatic factors.

These problems will likely become more acute as pure and concentrated chemicals supplant the older ordinary fertilizers. The older fertilizers, consisting of plant and animal by-products, and even the inorganic fertilizer salts originating in natural deposits and containing greater or less amounts of accompanying impurities, are increasingly being supplanted by manufactured products of a high degree of purity, especially the air-derived nitrogen products. The application of these chemical fertilizer substances to the general run of soils containing sufficient reserves of the lesser inorganic constituents is not likely to involve any problem of deficiency. On the other hand, in soils, and especially sandy soils, where the amount of these less common constituents may be small or unavailable, deficiency will probably be noticed in time if pure chemicals only are used. In the problem described in connection with tomato growing in Dade County, Florida, the heavy applications of inorganic fertilizers, while furnishing an adequate supply of the major nutrients, could not meet the deficiency of manganese in the soil, but the manure procured from soil regions well supplied with manganese apparently carried sufficient quantities to supply the demands of the plant.

These striking effects of manganese deficient soils in southern Florida, which I have shown you, have also been indicated in other sections of the country, and the importance of extending this experimental work to include other crops and other soil regions where crop difficulties are experienced is evident. Recent experiments have also shown that small quantities of other of the less common elements are of tremendous importance in crop production. Artificial fertilizer practice must take into consideration the role of manganese and other elements, which may be proved indispensable to plant growth and function, determining these deficiencies in soils and meeting them through appropriate supplements to the fertilizers applied.

Another striking illustration of the effect of minute quantities of the less common plant food elements, especially of copper, occurs in the work of Allison on Everglades peat. These peat lands present many problems and among them has

been the lack of response to fertilizers. Allison has obtained plant growth responses on a long list of plants by using such unusual fertilizing elements as zinc, antimony, nickel, tin, barium, copper, and manganese. Of these the most favorable results were obtained with copper and the residual effects of this treatment have carried over for more than a single cropping season. By the use of copper, plant growth has been enormously stimulated, and although the problem is not yet solved, this research by Allison holds out much promise for the future of the Everglades.

The treatment of Everglade peat lands with copper sulphate has now reached commercial proportions, and a considerable acreage devoted to sugar cane is now thus treated in the region south of Lake Okeechobee. Previous attempts to grow sugar cane on a large scale in the Everglades north of Miami practically failed and even experiments using all possible combinations of fertilizers, as is done in the triangle work familiar to you, failed to give us any promising leads. This new treatment, together with proper fertilizer use, is giving very encouraging results in the practical utilization of these extensive Everglade peat lands.

Interesting in this connection is also the now common practice of applying copper sulphate to citrus trees suffering from dieback, which is considered a physiological disease. The symptoms of dieback are many, among them chlorosis or mottled leaf, gum pockets in the new shoots, and multiple buds, similar to those observed by Reed and Haas with incomplete culture media. Originally, the crystals of copper sulphate were inserted under the bark with only moderate success, but for the last ten years or more the copper sulphate has been applied in fertilizers or separately to the soil. Beneficial results are obtained often enough to encourage citrus growers in the practice of using copper sulphate as a cure for dieback.

Miss Sommers has been doing some very valuable work on the effect of the less common elements on plants at the University of California laboratories with Dr. C. B. Lipman and is now continuing her researches at the University of Minnesota. Copper is proving to be absolutely essential for the normal growth of sunflowers and tomatoes, but the amount necessary is exceedingly small. Nevertheless, even mere traces of copper in the culture solutions caused an increase in growth of tomato plants over ten times that produced with copper absent. A single leaf of the copper-treated plant was often greater than the entire plant without copper.

Sommers has likewise done some excellent work with boron and with zinc and this latter has also given marked results

which seem to indicate that it too is essential to growth. The evidence, however, that zinc is really essential is rather conflicting in the experiments recorded in the literature, and no agricultural value can as yet be assigned to its compounds.

I rather hesitate to bring up the subject of the essential character of boron to plant development and crop production. Unpleasant memories of its presence in excessive amounts in fertilizer salts during the war, with extended crop damage of millions of dollars followed by prolonged law suits and government control, are no doubt called up when boron is mentioned. It was a distinct achievement of the American Fertilizer and Chemical Industry that it so rapidly and effectively solved for all time the danger which lay in the presence of an excess of boron in fertilizers. We all condemned boron at that time and it is therefore fitting that a few good words be said in its behalf. Boron is an admirable illustration of the principle that these rarer plant foods must be handled with care and understanding, without them, no plant development, no maturation, no fruition, but excessive amounts cause damage and crop failure. Scientific control of the amounts supplied in seed, soil, irrigation water, and fertilizer are essential and show us that the old days of haphazard experimentation and practice are not possible, when these new forces and factors are brought into play.

Even while we were demonstrating during the war period the toxicity of boron and determining the limits which might be tolerated in fertilizer salts, B. E. Brown, of the Bureau of Chemistry and Soils, showed that small amounts of the salt borax could not only be tolerated by such crops as potatoes, but that increased growth and yield resulted with one, two, or three pounds of borax per acre, or approximately one part of borax per million of soil. The subject has since been investigated by Brenchley and Warington at Rothamsted in England, by Sommers and Lipman in California and by Johnston and Dove in Maryland.

Brenchley, working with the leguminous plants, not only showed the essential character of boron to plant growth, but demonstrated that in the broad bean the boron was absolutely essential in the production of the vascular system or ducts of the legume nodule which enables the plant to obtain the much needed nitrogenous matter from the nodule and in return supply sugars and other food substances to the bacteria in the nodules, thus enabling them to grow and develop and fix more nitrogen, a truly remarkable system of cooperation between plant bacteria and boron.

Sommers, as mentioned, has shown boron to be essential to

a long list of plants, and Johnston, working with the tomato, has demonstrated quite conclusively its importance in plant growth. While the exact role that boron plays in plant growth is still a subject for further study, it may be pointed out that the growing points and other meristematic tissue seem to be greatly affected by a deficiency of boron and that another striking symptom is a breakdown of the conducting system as demonstrated by microscopic examination and chemical analysis. In the boron deficient tomato plants the starch and sugars were more abundant in the leaves and stems than in the corresponding tissues of normal plants. Starch and sugars were manufactured but could not be transported from the leaves and stems, a fact harmonizing with the nodule-plant exchange noted by Brenchley. Another interesting growth effect was noted by Johnston with boron-free potato plants in which the leaves showed not only a high starch content but also the characteristic symptoms of what is known as the potato leaf-roll disease. All these abnormal symptoms are obviated by adding as little as half a part per million to the culture solution. Toxicity, however, was reached with as little as five parts per million.

The absolute necessity of the small amount of boron for normal growth is demonstrated and this element must therefore be considered as essential, but an excess must be avoided. Boron is so widely distributed in minute amounts throughout natural soils and fertilizer materials, that its addition for agricultural use is probably nowhere necessary except possibly in sandy soils with high rainfall where the purely synthetic nitrogen and other fertilizer salts are used continuously. This boron question from a fertilizer viewpoint, is however, a problem of the future rather than the present, but illustrates the accurate scientific control that must be exercised in the study and use of some of these less common but nevertheless essential plant food substances.

It is not possible to review here all the evidence on this question of essentialness of the rarer elements to plants and animals, but I do not want to leave the subject without pointing out to you the tremendous value to human and animal life and freedom from disease of the presence of these elements in the food we eat and the feed we give to our stock. Iodine is essential to prevent the dread goitre in man and abortion in cattle and hairlessness in young pigs; copper and manganese play their part in the formation of blood and the prevention of anemia, and it has been shown that these constituents are wisely stored up in the unborn child or animal to enable it to function properly until it can get its own supply later in its food, since mother's milk or cow's milk does not supply these essential elements at the start. As you know, liver which con-

tains copper compounds, is now being prescribed even for pernicious anemia; low calcium and phosphorus content cause many serious diseases in cattle. Numerous other illustrations might be cited. The best and normal way for nature to supply these elements, as well as the other essential mineral elements, to animals and to man is through their feed and food, through plants, vegetables and fruits, grown on fertile well-fertilized soils.

Probably the most important change in fertilizer practice in recent years, to which I shall refer briefly, has been the introduction and use of what is now referred to as concentrated or high-analysis fertilizers. You are familiar with this trend in that it has tended to gradually eliminate not only low-analysis mixtures, but to greatly reduce the number of so-called "Brands" which were in high esteem twenty to twenty-five years ago. You are also fully aware that the movement to increase the plant-food content of fertilizer mixtures during the past ten to fifteen years has led to marked changes in fertilizer composition and concentration and application. I need not dwell on the influences which have played a part in this forward movement except to state that the fertilizer industry itself has played a leading part in connection therewith.

When it was suggested a number of years ago that the plant food content of fertilizers might profitably be increased, not much active interest was displayed. Those advocating the change to higher-analysis fertilizers stressed the economies that would be effected, not only in the fertilizer factory, but on the farm as well. It was pointed out that less hauling, bagging, and storing would be required and the cost of fertilizers reduced accordingly. To the farmer would accrue savings in freight, hauling and handling. While the suggestion evoked interest among professional men at the time, it did not appeal much to the fertilizer trade. But matters changed considerably as a result of the World war. Fixation of nitrogen from the air for the manufacture of death-dealing explosives had developed to gigantic proportions. The nations most active in developing methods for nitrogen fixation and building huge chemical plants in which to produce the various nitrogen materials found it necessary to establish a peacetime outlet for these products. The natural outlet was through the fertilizer trade. It soon became evident that the production of synthetic nitrogen materials was developing at a fast rate, particularly abroad, and coincident with this expansion, and in view of the high analysis of the new materials, the agitation to increase the plant food concentration of fertilizers was given greater and more serious attention by various agricultural agencies and the fertilizer industry. As just stated, one of the main factors was the high plant-food concentration

of the newer materials. I will mention, for example, urea, which, as you know, contains 46 per cent of nitrogen; ammonium nitrate, with 35 per cent of nitrogen; ammonium chloride, with 26 per cent of nitrogen and various salts containing two and occasionally three plant-food elements. Material followed material until it was difficult to keep pace with them. Not only were nitrogen materials introduced, but as indicated, salts like ammonium phosphate or "Ammo-phos," potassium phosphate, potassium ammonium phosphate and many special materials like Nitrophoska, Leunasalpeter, Leuna-phoska, Ammo-phos-ko, etc., were offered to the fertilizer trade and in turn to fertilizer consumers.

These new highly-concentrated salts or salt mixtures have made it practicable to increase the concentration of fertilizer mixtures and so, during the past decade, particularly the last five years, great strides have been made toward the development and use of concentrated fertilizers. It became necessary to conduct field studies in order to compare the behavior of concentrated or high-analysis fertilizers toward plant growth and crop production with that of ordinary-strength fertilizers. Certain serious questions had arisen in the minds of growers concerning the use of concentrated fertilizers. Chief among the questions raised was: How will concentrated fertilizers compare in cost with ordinary-strength fertilizers? The answer to this is that concentrated fertilizers can be delivered to the farmer at less cost per unit of plant food than ordinary-strength fertilizers. In other words, a ton of, let us say 7-6-5 will cost more delivered to the farmer than one-half ton of 14-12-10, both of which contain the same quantities of plant food.

Another question was: Can concentrated fertilizers be prepared and delivered to the farmer in good physical condition, so that no trouble is experienced in applying them uniformly and without waste? In the light of present knowledge, the answer to this question is, yes. By the proper selection of materials and the avoidance of too much hygroscopic material, we have found this season, for example, that treble-strength fertilizer mixtures prepared in our fertilizer house in Washington and shipped to Aroostook County, Maine, involving a period of a month or two under variable atmospheric conditions, were in excellent physical condition and were applied with the potato growers' regular planting machinery with fertilizer attachment without trouble and the applications were quite uniform.

The production of synthetic fertilizer salts is increasing rapidly in the United States; so much so that one hestitates to attempt an estimate of what is going on today when tomor-

row may see marked changes. A few months ago, however, it was reported that in 1929 seven American plants produced 100,000 tons of synthetic ammonia, something more than three times the output of 1928, with new plants being installed in both California and Michigan and one large company already expanding its $125,000,000 plant in Virginia.

Research is the backbone of your industry; research involving methods of mixing materials and the reactions involved; research connected with the storage of fertilizer mixtures; research affecting conditioning materials; and research connected with methods of applying fertilizers to different crops and their effects on plant growth and production.

Research is also the backbone in synthetic nitrogen production. Millions are being expended by the leading companies. No great stretch of imagination is needed to sense how far these powerful interests will go during the next ten to twenty years,—perhaps less. Such tremendous efforts on the part of this highly-specialized industry will have to be adequately met by investigational work under laboratory, greenhouse and field conditions to determine the agricultural value of the nitrogen materials produced.

A third question is: Will concentrated fertilizers give as satisfactory yields as ordinary-strength fertilizers? For some soil types with high water-holding capacities and well distributed rainfall, the answer is generally yes. For lighter soils, where a drought is apt to occur, such as has been experienced in certain sections this season, there remain yet a number of important problems to solve before a positive answer is forthcoming. We need, for example, to make a comprehensive field study of methods of fertilizer placement and distribution on prominent soil types also, the effect of heavy rainfall on the comparative effectiveness of concentrated and ordinary-strength fertilizers. There are other problems, such as a study of the movement of these highly soluble salts in different soil types, but I shall not attempt to expand the subject at this time.

A fourth question which brings us back to the essential minor plant food elements is: Will these synthetic salts, relatively pure in composition, tend to force a depletion of the minor elements, particularly in soils subject to leaching. The so-called minor element, if lacking as a result of exhaustion by crops, becomes one of major significance, and the presence of ample supplies of the major elements, nitrogen, phosphoric acid and potash, will not counteract a deficiency of either magnesium, manganese, copper, boron, iodine, or the like. Considerable study will be necessary to determine if and how

rapidly depletion of these minor elements takes place from soils under continued cropping and continued use of pure synthetic fertilizers. It may well be that the fertilizer manufacturer may have to consider the introduction of minor elements in his fertilizer mixtures to offset the purity of synthetic salts.

Fertilizers Increase the Total Yield and Percentage of Large Sized Potatoes*

A. W. BLAIR, Agricultural Experiment Station, New Brunswick, N. J.

Varying amounts of a concentrated fertilizer analyzing 16 per cent nitrogen, 32 per cent phosphoric acid, and 16 per cent potash were used for potatoes on Sassafras loam soil in 1930, in comparison with a standard fertilizer analyzing 5 per cent nitrogen, 10 per cent phosphoric acid, and 5 per cent potash, used at the rate of 1,600 pounds per acre as a control. One-half the nitrogen in this fertilizer came from nitrate of soda and one-half from sulphate of ammonia. Following the potato crop of 1929 this land was seeded to rye as a green manure crop. This made excellent growth and on the 1st of April, 1930, it was plowed down. A sample including roots taken from a square yard at the time of plowing was washed, dried and prepared for analysis. The weight of this dried sample was approximately two pounds and the nitrogen content was 1.38 per cent. Calculated to the acre basis this means that the green manure crop supplied between 9,000 and 10,000 pounds of dry matter per acre and carried nearly 140 pounds of nitrogen. It must be understood, however, that a large part of this nitrogen would probably not become available rapidly enough to do the immediate crop very much good.

The land was put into good condition and Prince Edward Island No. 1 Certified Irish Cobbler seed was planted April 15, the fertilizer having been applied in the row by hand the

*Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Soil Chemistry and Bacteriology.

previous afternoon. With the exception of two plots that received the 16-32-16 fertilizer at the rate of 1,000 pounds per acre, a good stand of potatoes was secured. Many of the plants on the 1,000-pound plots were delayed in coming up and some did not come through the ground.

The vines grew nicely and were sprayed with Bordeaux five or six times. During the extreme hot weather in July, the plants on the plots which received the small application of fertilizer (250 pounds per acre) began dying. By the 28th of July the majority of plants on these plots were practically dead. On the other hand, the majority of the plants on the plots that received 750 and 1,000 pounds per acre were still fairly green. In appearance the control plots stood between those with the low and high application of 16-32-16 fertilizer. Vines on the plots that received the 750 and 1,000 pounds per acre were still somewhat green when the potatoes were harvested August 11th.

The yields of primes and seconds (including those smaller than seconds) for the different plots are indicated in table 1. A careful study of the table brings out the following interesting facts. The highest yields were obtained with the 750-pound application and these yields are sufficiently above the yields of the 500 pound application to justify the increased amount.

The yields with the 1,000 pound application are less than those with the 750 pounds. It was very evident in this case that there was injury with the 1,000 pounds of fertilizer. Germination was slow on these plots and a number of the plants never came through the ground. However, those that did come up made excellent growth and the potatoes were large, as indicated in the table showing percentage of seconds. Had the fertilizer been more thoroughly mixed with the soil, or had half been put on at planting and the other half later, it is very probable that no injury would have occurred.

Taking the average, the control plots gave slightly better yields than the plots that received 500 pounds of 16-32-16 (equivalent amount of plant food), but the cost of handling the larger amount of the former would probably over-balance the gain in yield.

Reference to the column showing the percentage of seconds shows that the amount of the concentrated fertilizer used bears an important relation to the quantity of small sized potatoes. The plots that received the 250 pound application show a very high percentage of seconds while those that received the 1,000 pound application show the lowest percentage. The averages for the different treatments are as follows:

Control	23.5	per	cent	seconds
250 lbs. 16-32-16	43.9	"	"	"
500 lbs. 16-32-16	30.2	"	"	"
750 lbs. 16-32-16	17.2	"	"	"
1000 lbs. 16-32-16	16.2	"	"	"

This difference in size was easily noted when the potatoes were dug. One is inclined to ask whether the increase in size must be attributed entirely to the increase in the total plant

TABLE 1.

Yield of Potatoes and Percentages of Seconds With Concentrated Fertilizer—1930

Plot No.	Fertilizer per Acre	Primes Bu. per Acre	Seconds Bu. per Acre	Total Bu. per Acre	Per Cent Seconds
94	Control	97.3	23.7	121.0	19.59
95	250 lbs. 16-32-16	68.2	39.5	107.7	36.68
96	500 lbs. 16-32-16	98.3	35.9	134.2	26.75
97	Control	106.9	31.7	138.6	22.87
98	750 lbs. 16-32-16	124.5	32.8	157.3	20.85
99	1000 lbs. 16-32-16	96.0	18.5	114.5	16.16
100	Control	98.2	35.9	134.1	26.77
101	250 lbs. 16-32-16	56.9	59.3	116.2	51.03
102	500 lbs. 16-32-16	94.5	48.0	142.5	33.68
103	Control	111.9	29.9	141.8	21.09
104	750 lbs. 16-32-16	143.2	22.3	165.5	13.47
105	1000 lbs. 16-32-16	98.5	19.0	117.5	16.17
106	Control	95.2	35.3	130.5	27.05

NOTE: The yields reported above will seem small to those who are located in the important potato growing districts, but it may be pointed out that the soil on the College Farm is not typical potato soil. It usually does well to give 150 bushels per acre.

food constituents or whether it may be due to only one or possibly two of the three plant food constituents. This experiment does not furnish a definite answer to this question. It may be suggested, however, that the 250 pounds of 16-32-16 furnish 80 pounds of phosphoric acid. Since a 100-bushel crop of potatoes (tubers only) requires only about one-eighth this amount of phosphoric acid, we are forced to the conclusion that there could not have been a deficiency of phosphoric acid. Furthermore, a test of different amounts of phosphoric acid on adjoining plots this year shows as high a yield of potatoes with 1,600 pounds of a 4-0-4 fertilizer as with the same amount

of 4-16-4. This tends to confirm the conclusion that phosphoric acid was not a limiting factor in the other experiment.

With reference to the two elements nitrogen and potash, the evidence is not complete. Two hundred fifty pounds of fertilizer carries 40 pounds of potash. This is probably all that could be used by a 100-bushel crop of potatoes. Furthermore, this soil is well supplied with potash. It would therefore seem probable that in the case of the 250 and 500 pound application, the higher percentage of small potatoes was due to a lack of available nitrogen. It is true that the 250 pound application carries 40 pounds of nitrogen, which is nearly enough for a 200-bushel crop of potatoes. On the other hand, there is a much greater possibility of loss of nitrogen than of the other two elements. Also once the potato plant is well started it grows rapidly and a large reserve supply of available nitrogen must be at hand if it is to continue this rapid growth. The splendid growth made by the plants on the plots that received the larger applications is evidence of this. As already suggested, much of the nitrogen in the green rye that was turned under could not have been made sufficiently available to help the crop at the critical time.

These results together with results secured in other experiments with potatoes emphasize the importance of a large reserve of readily available nitrogen if the vines are to be kept growing so that they will give a large yield of good sized potatoes.

Crop and Market News

(Contribution from the Bureau of Agricultural Economics)

CROP PROSPECTS SLIGHTLY INCREASED

Potato markets were very weak and prices were declining nearly everywhere during mid-October. Carlot movement was quite liberal, but could hardly be termed excessive. Colder weather was needed, to stimulate the market. Prices generally were at least one-third lower than last autumn, part of this condition probably being due to the depressed business situation.

Progress of potato harvest in the late states indicated that yields will likely average somewhat higher than was expected in September, when the uncertain effect of extensive drought was a primary consideration. The United States production of all potatoes, early and late crops, combined, was forecast at 352,200,-

000 bushels, on the basis of conditions and expected yields reported October 1. This represents an increase of 13,000,000 bushels, or nearly 4% over the September 1 prdouction prospect.

The present forecast indicates that production this year will be 2% smaller than the 1929 crop and almost 11% below the average production for the previous five years. Production in the 19 northern states, usually having a surplus of late potatoes for shipment, was forecast at 237,160,000 bushels, or 8,000,000 bushels (3.5%) more than expected in September, although still 8,000,000 bushels below 1929 production and about 37,000,000 bushels below the five-year average. In 16 other northern states, which usually have a deficient supply of late potatoes, prospects increased more than 4,000,000 bushels (6%) during September, the crop now being forecast at 78,570,000 bushels.

Shipments of potatoes reached a high mark of 7,300 cars during the opening week of October, and then decreased temporarily to 6,700 the second week. Movement at that time was much lighter than a year ago, and the leading late-crop states were about one-sixth short of their record during the early part of last season. Markets were showing customary weakness during the period of active digging of potatoes.

F. O. B. prices showed a general decline, with a range of $1.25-$1.35 in northern Maine, $1.55-$1.60 in western New York, and $1.40-$1.50 in the north central area. Shipping-point values in Nebraska and Colorado were down to $1-$1.30 per 100 pounds and the southern Idaho cash-track market on best Russet Burbanks had dropped to $1, with Rurals returning 90c-95c. Yakima Valley shippers were getting $20-$25 per ton of sacked combination-grade Russet Burbanks. The Chicago carlot market was dull, most sales ranging between $1.40 and $2 per 100 pounds.

Tabb Potato Service, Chicago, Ill., Oct. 23, 1930

THE OCTOBER FREEZE

Some of the coldest weather on record for a great many years has prevailed over quite a few states from Chicago west during the past week or ten days, and the damage to potatoes has been considerable in several instances. There is not a great deal than we can add to our special frost damage letter of October 18th, but we will review the situation briefly in the affected states.

IDAHO

The territory north of Pocatello, Idaho, experienced some very low temperatures during the night of Wednesday, October 15th. The thermometer dropped to around 20 at Idaho Falls and to around 15 at St. Anthony. The frost damage ranged from a moderate nipping of partially exposed potatoes around Pocatello to from 40 to 50% actual damage on the Egin Bench and nearby sections in the vicinity of St. Anthony. Sixty per cent of the crop was undug in this territory, and of this amount about 15% was frozen beyond recovery. The loss is estimated at from 1,500 to 2,000 cars, or somewhere between one and two million bushels. It is very probable, however, that the Idaho estimate for October was so low that it may not be necessary to change the final figures for the state.

COLORADO

The big bulk of the Colorado crop was safely harvested before the frost of October 12-15, but a few fields were caught, especially in the San Luis Valley, to a certain extent. The damage was not material, however, and may be largely ignored.

NEBRASKA

Between 30 and 35% of the acreage in the Alliance-Hemingford district was undug when the frost came last week, also approximately 25% in the Kimball section and 10% in the Platte River valley. The average for western Nebraska was about 25% unharvested acreage. Temperatures dropped to as low as 15 degrees at Alliance for two nights and there has been some rain since. It is thought that between 25 and 40% of the potatoes in the ground in western Nebraska are not worth harvesting. The fact remains, however, that western Nebraska had a wonderful crop, which our information indicates was not fully covered by the October crop estimate of 8,280,000 bushels. Our correspondents estimate that had the frost held off until harvesting was completed, Nebraska would have harvested 10,000,000 bushels of potatoes this fall. The loss from the frost is thought to be from 1,000,000 to 1,500,000 bushels, which would indicate that there are still more potatoes left than the government October figures showed.

MINNESOTA-NORTH DAKOTA

The latest check that we have on the Red River Valley indicates that approximately 25,000 acres were unharvested in the valley proper from Barnesville north to the Canadian line. Temperatures in the valley ranged from 12 to 20 degrees for

five consecutive nights, and the ground was frozen severely. The weather has moderated this week, but everyone in the valley says that the potatoes left in the ground are not worth digging and no effort has so far been made toward salvaging this undug acreage. The loss in the Red River Valley alone should run close around 2,500,000 bushels, not counting the stock frozen in temporary storages.

The entire state of Minnesota is seriously damaged, although there were not a great deal of potatoes in the ground outside of the Red River Valley. Hundreds of growers, however, particularly in the sand land district, had placed their potatoes in temporary shallow pits at digging time, with the idea of sorting them out or covering them deeper before freezing. Also, a great many potatoes (some say 10%), all over the state were in temporary storages such as barns, hen-houses, garages, sheds, and other unprotected shelters. Practically all of these potatoes have been frozen more or less. One farmer near Princeton had 700 bushels stored in a barn, and he expects to lose half by reason of the cold weather. The frost loss in Minnesota and North Dakota could easily total 5,000,000 bushels, although the next government report will not show that much of a reduction.

WISCONSIN

There were from 20 to 25% of the commercial potatoes in the central area of the state that were undug when the frost came. There were also scattered fields over the remainder of the state and it is thought that probably 10% of the entire Wisconsin acreage was in the ground when the freezes came. Temperatures ranged from 15 to 22 for five or six days, and it is very doubtful whether any of the potatoes in the state will be much more than worth digging and marketing. The Wisconsin loss undoubtedly ranges from 1,000,000 to 2,000,000 bushels, depending upon how much of the stock in temporary storages is affected.

MICHIGAN

Information from various sources this week indicates that not more than 60% of the Michigan acreage has been dug. Temperatures were below freezing for several nights in this state, and on Tuesday of this week the mercury dropped to 18-20 in most of the best producing districts. It is impossible to ascertain at present how much damage has been done, but practically all of the warehouses in the lower peninsula have been closed, or at least the shippers are not buying any of this stock dug since Tuesday night. Unless another freeze comes, however, before harvest is completed, the Michigan damage

will not be as great as in either Wisconsin or Minnesota, but it is sufficient to cause a lot of trouble and delay this fall.

NEW YORK

Most of western and central New York had considerable snow early this week, but temperatures did not drop generally below 26-28 degrees. Some field frost is reported in all sections, but not serious; probably not to exceed one per cent loss. In western New York the crop is from two-thirds to 90% harvested, while in central New York not much more than 50 or 60% of the crop is dug. Many of the hill fields are still green, and it is probable that the crop for upstate New York as a whole has improved more this month than it has been damaged by frost so far. The same is true of the northern counties in Pennsylvania, where temperatures have not been low enough to cause material damage.

Notes

THE CANADIAN CROP

Crop expectations in Canada on October 1st indicated a total yield of 47,262,400 cwt. (78,770,665 bushels) of potatoes this season, compared with 41,950,000 cwt. last month and 39,930,000 cwt. last season. The estimated yields in cwt. by provinces are as follows, with comparisons since 1926; (000 omitted):

October	1930	1929	1928	1927	1926
Pr. Ed. Island	4,500	3,820	5,698	4,418	4,603
Nova Scotia	3,100	2,872	3,280	2,680	3,115
New Brunsw'k	4,653	4,646	6,776	4,204	6,090
Quebec	13,790	15,429	13,071	14,175	14,676
Ontario	11,250	8,484	11,875	9,297	9,898
Manitoba	3,193	1,161	2,585	2,324	2,355
Saskatchewan	2,460	1,149	3,052	3,849	2,232
Alberta	2,576	1,022	2,220	3,241	2,033
British Col.	1,740	1,347	1,628	2,270	1,935
Total	47,262	39,930	50,185	46,458	46,937

TABB POTATO SERVICE.

Crop conditions in early September indicated a yield of seventy million bushels, an increase of only five per cent over the short crop of last year. Some losses from blight have since occurred in some areas and a further reduction in the estimated production may be found necessary.

Complete returns covering the certified seed crop are not yet available but those received indicate that approximately 25,000 acres planted passed all field inspections, and that the seed crop will total between four and five million bushels in 1930.

—J. TUCKER.

COLORADO

The Gylling and Finley Potato Ranch

The Costilla Land Grant was an old Spanish estate of 500,000 acres bestowed by the Spanish Crown, centuries ago, upon some court favorite when Spain controlled all southwest portion of North America.

For years the irrigated lands in the north portion of this grant now in the county within the San Luis Valley named after the Grant—Costilla—were thought not capable of growing quality Irish potatoes.

Five years ago on a Farm Demonstration Train, Dr. E. P. Sandsten, head of the Colorado Horticultural work which includes the potato work at Colorado Agricultural College, told the Costilla county farmers they could grow potatoes successfully, "if they would supply the plant food potatoes need and require —plenty of humus for them to feed upon. Grow sweet clover, alfalfa or pod peas and plow this crop under green. Plant good quality seed potatoes, take good care of the crop, keep down weeds thoroughly, till the ground and give just enough irrigation to keep the ground reasonably moist and dissolve the plant food in the soil and you will harvest table stock potatoes in this part of the country, the same as in other parts of this big mountain valley." Since then, several farmers have put in several small acres as Dr. Sandsten advised and have gotten good results.

Not until this last spring has any large farm acreage been attempted. Mr. Carl Gylling and R. K. Finley came across the Rio Grande river from the west side to Costilla county on east side of the Rio Grande, resolved to plant a commercial acreage of potatoes on a certain farm in the vicinity of Mesita, near the center of Costilla county.

They first looked up the land for sale, investigated its soil, its water and then secured the potato farmers to help them put Dr. Sandsten's suggestion to the commercial test.

Mr. Wm. Crounk and Fred Crow, most successful potato farmers from a proven potato district—the LaJara—were secured to direct this work and a 480 acre farm purchased. Some 120 acres of this farm had been in field peas for eight years and 80 acres had been down in alfalfa for 12 years. Gylling and Finley did not get possession of the land until March 1st, this season. So no fall plowing was possible and neither could a crop be turned under green. They did the best they could. They let farmers Crounk and Crow plow up those fields of alfalfa and field peas good and deep and make the best seed bed for potatoes they knew how to make, from their previous experience. From a man in the Mesita district, who was growing certified seed potatoes in a small way under Professor Carl Metzger, associate professor of horticulture at the college in charge of potato certification work, some seed potatoes were secured and some from Dr. Meinzer, a grower of certified seed potatoes within the LaJara district where Messrs. Gylling and Finley live, and the rest of the Peachblow seed was obtained as best the farm owners could get. Needless to say good farming methods were followed on this Gylling-Finley potato ranch throughout the growing season. The height of the vines was practically waist high and the potato rows were a full mile long and before the vine growth took the field, showed the full length of the field, straight as a gun, with scarcely a weed within the entire 200 acre potato patch.

The night of Sept. 11th the first killing frost came. The vines did not die down fully so digging could begin, until the last of the month.

The fore part of September a large potato cellar 50x160 ft. was built to hold the major portion of the crop in storage. This cellar has a capacity of 22,000 bags of approximately two bu. each. At present time that big cellar is full of potatoes, 15 cars of potatoes have been dug and shipped and 50 acres are yet to be dug.

The 80 acres of former alfalfa land the writer can report on as its potatoes were all harvested just six days ago (Oct. 10th).

This alfalfa land gave an average yield for the entire 80 acres of 200 sacks per acre, practically 400 bushels. County Agent Martin of Costilla county measured off ten acres near the center of the field and by weight of these potatoes gave an average yield of 638 bushels for each of those ten acres. This

entitles farmers Wm. Crounk and Fred Crow to enter Professor Carl Metzger's 600-Bushel-per-Acre club for Colorado.

One of their neighbors in an adjoining town—San Acacio—Mr. Frank Peterson grew 23 acres of the same type potatoes on which he produced 370,000 lbs. of table stock potatoes that graded U. S. No. 1 and besides this had 65,000 lbs. of seed potatoes. County Agent Martin measured up an acre out of the 23 that gave by weight a yield of 604 bushels of Peachblows. This, of course, entitles Farmer Peterson to enter the Colorado 600-Bushel club, making three from this one county where, before Dr. Sandsten told them differently, farmers believed potatoes could not be grown.

These commercial demonstrations of the soundness of Dr. Sandsten's advice will give a real endorsement of the potato industry as adapted to the climate and soil of Costilla county, Colorado.

The work of Farmers Crounk and Crow this season on the Gylling-Finley Mesita farm has indeed been a most profitable and successful commercial demonstration of the value of Dr. Sandsten's Demonstration Train Potato Talk five years ago.

From now on this farm will grow a seed plot planted to that type of Peachblow Dr. Sandsten and Professor Metzger advise and recommend.

—W. H. OLIN.

NEW YORK

The Midwinter Potato Convention at Syracuse

It will be held at Hotel Syracuse on January 7 and 8. The show will be set up on the 6th. The directors and committeemen will have a joint dinner with the directors of the State Vegetable Growers' association on the evening of the 6th. The program promises to include everything new in potatoes and will be comprised of four half-day sessions. Two widely-known speakers, who have never before appeared on a potato program in New York, have already been engaged. Extra exhibit space has been provided to relieve the crowded condition that existed last year. The annual banquet and entertainment is scheduled on the night of January 7th. And don't forget the trade show. The trade show committee is figuring space for about 30 vegetable and potato trade exhibits to fill the entire wall space of the grand ball-room of Hotel Syracuse.

—E. V. H.

KENTUCKY

Copper-Lime Dusting of Potatoes in Kentucky, 1930

Dry-Bordeaux application on potatoes intrigues us in Kentucky for several reasons. These include speed in coverage, smaller investment in apparatus, and the lack, in many cases, of adequate spraying water.

The history of the use of copper-lime dust in Kentucky has been hectic, even controversial, and our tests for 1930 offer to some, no cause for abatement of the controversy, the controversy being about whether to dust or whether to do nothing. As between dusting or spraying there is no controversy; we lean to spraying when and where it is practicable.

Three demonstrations were conducted in the Louisville district on farms on which the practice is to dust. The demonstration consisted merely in leaving checks untreated except for Colorado beetle control, with Paris Green.

The sizes of the demonstrations were not the same throughout, but the pairs of "treatments" in each case were. The acre application was 60 pounds of standard copper-lime dust with poison included, in three dustings. The data follows:

Demonstration No. 1 (Stutzenberger):

Grades	Dusted Plot	Undusted Plot
No. 1	1262	1432
No. 2	250	280
No. 3	56	67
Culls	26	27
Total yield	1594	1806

Demonstration No. 2 (Moser):

Grades	Dusted Plot	Undusted Plot
No. 1	1618	1481
No. 2	148	166
No. 3	32	40
Culls	49	52
Total yield	1847	1739

Demonstration No. 3 (Moser):

Grades	Dusted Plot	Undusted Plot
No. 1	1311	1160
No. 2	111	113
No. 3	21	27
Culls	11	8
Total yield	1454	1308

For demonstration No. 1, in which copper-lime dusting gave a decreased total yield of 11.9 per cent (of the untreated) we venture to submit that the advantage in soil fertility lay with the untreated plat; that the site for the demonstration was chosen unfortunately.

In the case of demonstration No. 2 the dusting gave an increase, in total yield, of 6.2 per cent, and of No. 1 tubers, 9.2 per cent.

In the case of demonstration No. 3, the dusting gave an increase, in total yield, of 11.2 per cent, and of No. 1 tubers, 13 per cent.

The season operated against even reasonable returns being realized, for almost no dew fell, after the time dusting began. Since this is an unusual condition with us, however, we who have faith in dusting with copper-lime dust, still adhere to the faith.

—JOHN S. GARDNER.

Review of Recent Literature

Cohen, Ruth L.—Factors Affecting the Price of Potatoes in Great Britain.—Univ. Cambridge, Dept. of Agr. Farm Econ. Branch Rpt. No. 15, 55 pages, July 1930. The author prefaces her discussion of price affecting factors as follows:

"This study represents an attempt to explain the course of potato prices in England from 1885,—when the Board of Agriculture first collected returns of yield per acre and amount of production —up to the present day. Special attention has been directed to two points (a) the relationship between changes in the prices of potatoes and changes in their acreage and (b) between their

price and the quantity of imports. Analysis of the factors considered are included under the following chapter headings:

I. Reliability of data; II. The relation between retail, wholesale, and growers' prices; III. Conditions of demand; IV. Intra-seasonal price movements; V. The trend of pre-war prices; VI. Intra-seasonal price movements in the pre-war period; VII. The relation of acreage and prices in the pre-war period; VIII. The post-war period; IX. Imports and exports."

The author's summary indicates among other things that the production of potatoes in Great Britain showed a declining trend from 1885 to 1898 and a rising one, on the average, from the latter date to the present time. That variability in price results from alteration in supplies and that imports move in the same direction as prices. Home production—the important factor as regards prices—varies largely as a result of alteration in the yield per acre; fluctuations in acreage are considered of less importance, (than yield) though by no means negligible. As a result of a careful analysis of a 16-year period the data indicated that in general, acreage was high when prices were high and low when prices were low, but that in the case of short period fluctuations, peaks in acreage usually correspond with depressions in price and vice versa. The opinion is expressed that apart from attempts to stabilize yields there is no substantial way to stabilize retail prices from season to season. Copies of this report may be purchased from W. Heffer & Sons, Ltd., Cambridge, England, for 2/6 net (approximately 61c).

—W. STUART.

Squirrel, J., MacLennan, A. H., and Carroll, J. A.—Potatoes. Ont. Dept. Agr. Bul. 352, 29 p. April, 1930.

The authors report the results of the following experiments. (1) Comparison of northern versus southern Ontario grown seed stock conducted at Guelph for a period of 4 years in which an average production of 204.5 and 196.3 bushels per acre respectively was obtained from the northern and southern seed. (2) A time of planting experiment with the Irish Cobbler and Green Mountain in which six dates were used May 6 and 20, June 3 and 17, and July 1 and 15. The average results from a 7-year test 1918 to 1924 indicate a fairly definite progressive ratio of decrease from the May 6 to June 17 planting. The July 1 planting was nearly 50 per cent less than the June 17 and the July 15 about one-fourth in actual bushels of that of July 1. (3) Comparative results from exposure of seed potatoes in different ways for three weeks before planting. Six methods were used; (a) in barn in light sprouts not removed; (b) in root cellar in light sprouts not removed; (c) in root cellar in dark sprouts not removed; (d) in greenhouse in light sprouts not removed; (e)

in root cellar in dark sprouts removed; (f) in open air sprouts not removed. The ratio of decrease was relatively uniform in the first five lots with a decided yield reduction from the last treatment. (4) Sets of different size ranging in weight from 1/16 to 2 ozs. resulted in a very definite decrease from the 1/16 oz. set and a fairly uniform progressive ratio between the other sizes. (5) Planting sets of equal weight with a varying number of eyes showed a gain in yield between 1 and 5-eye sets but the 1-eye set produced a larger sized tuber. (6) A study of the relative value of sets from the stem, midde portion and seed end of the tuber showed an increased yield from the middle portion of the 5-year period of about 7 bushels over the stem end and of nearly 13 bushels per acre over the seed end. (7) Comparison was made of the relative influence on seed cut 4 or 5 days in advance of planting and freshly cut seed. The average of an 8-year test indicated a yield of 170.1 bushels from the fresh cut sets as against 162.3 bushels per acre from the other, a difference which can hardly be regarded as significant. (8) A 5-year test of the influence of plaster and lime sprinkled on freshly cut sets showed some advantage of land plaster over lime and of a considerably greater increase over untreated seed. (9) In a 7-year depth of planting test in which a 1-inch, 3-inch, 5-inch and 7-inch covering was compared the 3 and 5-inch depths gave best results. Several other cultural subjects are discussed in this bulletin and it should prove of great value to potato growers not only in Canada but the United States as well.

—W. STUART.

Announcement of the Annual Meeting

of the

POTATO ASSOCIATION OF AMERICA

to be held at

CLEVELAND, OHIO

December 29-30-31, 1930

An excellent program is being planned that will be of real interest to growers, dealers and workers in research and extension problems.

Papers to be read at the Annual Meeting are solicited at this time. Please send the title of paper to the Secretary.

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